

Chapter 2

Cartographic Standards

The following cartographic data standards were developed through an iterative process involving both the NASA Planetary Cartography Working Group (PCWG) and the PDS. Members of the PCWG are also on the key International Astronomical Union (IAU) committees which set these same standards for international adoption; therefore, the PDS-adopted cartographic standards are consistent with the IAU standards. The PDS, rather than making unilateral decisions on cartographic data standards, looks to the PCWG as the controlling body for these standards within NASA and the PDS. It is recognized that the IAU continually reviews its standards and may, at some time, make a change affecting the cartographic standards. If this happens, the PDS will work with the PCWG and decide its own course of action at that time.

Cartographic standards used in a data set should be identified, and where helpful, documented on an archive volume.

2.1 Inertial Reference Frame/Timetag/Units

The Earth Mean Equator and Equinox of Julian Date 2451545.0 (referred to as the "J2000" system) is the standard inertial reference frame. The Earth Mean Equator and Equinox of Besselian 1950 (JD 2433282.5) is also to be supported because of the wealth of previous mission data referenced to this system. The transformations between the two systems are to be available. Time tagging of data using UTC in Year, Month, Day, Hour, Minute and decimal Seconds is the standard, with Julian Date being supported. SI metric units, including decimal degrees, are the standard.

2.2 Spin Axes and Prime Meridians

The IAU-defined spin axes and prime meridians defined relative to the J2000 Inertial Reference System are the standard for planets, satellites and asteroids where these parameters are defined. For other planetary bodies, definitions of spin axes and prime meridians determined in the future should have the body-fixed axes aligned with the principal moments of inertia, with the North Pole defined as along the spin axis and above the Invariable Plane. Where insufficient observations exist for a body to determine the principal moments of inertia, coordinates of a surface feature will be specified and used to define the prime meridian. It is expected that some small, irregular bodies may have chaotic rotations and will need to be handled on a case-by-case basis.

2.3 Reference Coordinates

There are three basic types of coordinate systems, body-fixed rotating, body-fixed non-rotating

and inertial. A body-fixed coordinate system is one associated with the body (e.g. planetary body or satellite). In contrast to inertial coordinate systems, the body-fixed system is centered on the body and rotates with the body (unless it is a non-rotating type), whereas the inertial coordinate system is fixed at some point in space.

To support the descriptions of these reference coordinate systems, the PDS has defined the following set of data elements (See *Planetary Science Data Dictionary* for complete definitions.):

COORDINATE_SYSTEM_TYPE
COORDINATE_SYSTEM_NAME
LATITUDE
LONGITUDE
EASTERNMOST_LONGITUDE
WESTERNMOST_LONGITUDE
MINIMUM_LATITUDE
MAXIMUM_LATITUDE
POSITIVE_LONGITUDE_DIRECTION

Currently, PDS has specifically defined two types of body-fixed rotating coordinate systems, Planetocentric and Planetographic. However, the set of related data elements are modelled such that definitions for other body-fixed rotating coordinate systems, body-fixed non-rotating and inertial coordinate systems can be added when the need arises. If this is the case, contact a PDS data engineer for assistance.

The definition of Planetographic longitude is dependent upon the rotation direction of the body, with longitude being measured as increasing in the direction opposite to the rotation. That is to say that the longitude increases to the west if the rotation is prograde (or eastward) and vice versa. Table 2.1 lists the rotation direction (prograde or retrograde) of the primary planetary bodies and the Earth's moon. It also indicates the valid longitude range for each body. In order to accommodate different traditions in measuring longitude, in the *Planetary Science Data Dictionary*, PDS defines a broad longitude range: (-180, 360). Table 2.1 indicates which part of that range is applicable to which body.

Table 2.1: Primary Bodies and Earth's Moon - Rotation Direction and Longitude Range

Planet	Rotation Direction	Longitude Range
Earth	Prograde	(0, 360) (-180, 180)*
Mars	Prograde	(0, 360)
Mercury	Prograde	(0, 360)
Moon	Prograde	(0, 360) (-180, 180)*
Jupiter	Prograde	(0, 360)
Neptune	Prograde	(0, 360)
Pluto	Retrograde	(0, 360)
Saturn	Prograde	(0, 360)
Sun	Prograde	(0, 360) (-180, 180)*
Uranus	Retrograde	(0, 360)
Venus	Retrograde	(0, 360)

* The rotations of the Earth, Moon and Sun are prograde, however it has been tradition to measure longitudes for these bodies as increasing to the east instead of the west. PDS recommends that the Planetographic longitude standard be followed, but it also will support the tradition. Therefore, the longitude range of (-180, 180) is supported for the Earth, Moon and Sun.

2.3.1 Body-Fixed Rotating Coordinate Systems

2.3.1.1 Planetocentric

The Planetocentric system has an origin at the center of mass of the body. Planetocentric latitude is the angle between the equatorial plane and a vector connecting the point of interest and the origin of the coordinate system. Latitudes are defined to be positive in the northern hemisphere of the body, where north is in the direction of Earth's angular momentum vector, i.e., pointing toward the hemisphere north of the solar system invariant plane. Longitudes increase toward the east, making the Planetocentric system right-handed.

2.3.1.2 Planetographic

The Planetographic system has an origin at the center of mass of the body. The planetographic latitude is the angle between the equatorial plane and a vector through the point of interest, where the vector is normal to a biaxial ellipsoid reference surface. Planetographic longitude is defined to increase with time to an observer fixed in space above the object of interest. Thus, for prograde rotators (rotating counter clockwise as seen from a fixed observer located in the hemisphere to the north of the solar system invariant plane), planetographic longitude increases toward the west. For a retrograde rotator, planetographic longitude increases toward the east.

2.4 Rings

Locations in planetary ring systems are specified in polar coordinates by a radius distance (measured from the center of the planet) and a longitude. Longitudes increase in the direction of orbital motion, so the ring pole points in the direction of right-handed rotation. Note that this corresponds to the IAU-defined north pole for Jupiter, Saturn and Neptune but the south pole for Uranus.

Longitudes are given relative to the ascending node of the ring plane on the Earth's mean equator of J2000. However, the Earth's mean equator of B1950 is also supported as a reference longitude because of the wealth of data already reduced using this coordinate frame. The difference is generally a small, constant offset to the longitude. All longitude values fall between 0 and 360 degrees.

Note that ring coordinates are always given in an inertial frame. It is impossible to define a suitable rotating coordinate frame for a ring system because features rotate at different rates. When it is necessary to specify the location of a moving body or feature, one must give the rotation rate and the epoch in addition to the longitude.

The *Planetary Science Data Dictionary* (PSDD) contains a set of data elements designed to describe ring-related longitudes. Please see the PSDD for these elements and their complete definitions.

2.5 Reference Surface

The Digital Terrain Model (DTM), giving body radius as a function of Cartographic latitude and longitude in a sinusoidal equal-area projection, is the standard. Mars is to be an exception where Planetographic latitude is to be used. Spheroids, ellipsoids and harmonic expansions giving analytic expressions for radius as a function of Cartographic coordinates are to be supported.

The Digital Image Model (DIM) giving body "brightness" in a specified spectral band or bands as a function of Cartographic latitude and longitude in a sinusoidal equal-area projection, and associated with the surface radius values in the DTM, is the standard. Mars is to be an exception where Planetographic latitude is to be used. DIMs registered to spheroids, ellipsoids and harmonic expansions are to be supported.

2.6 Map Resolution

The suggested spatial resolution of a map is $1 / 2^n$ degrees. The suggested vertical resolution is 1×10^m meters, with m and n chosen to preserve all the resolution inherent in the data.

2.7 References

The following references give more detail on the cartographic data standards:

Davis, M. E., et al (1991) "Report of the IAU/IAG/COSPAR Working Group on Cartographic Coordinates and Rotational Elements of the Planets and Satellites: 1991," *Celestial Mechanics*, 53, 377-397.

Batson, R.M., (1987) "Digital Cartography of the Planets: New Methods, its Status and Future", *Photogrammetric Engineering & Remote Sensing*, 53, 1211-1218.

Greeley, R. and Batson, R.M. (1990) *Planetary Mapping*, Cambridge University Press, Cambridge, 296p.